SUBSURFACE BRACHIOPODA FROM BOREHOLE CORES THROUGH THE EARLY PERMIAN SEQUENCE OF THE CARNARVON BASIN, WESTERN AUSTRALIA: CORRELATIONS WITH PALYNOLOGICAL BIOSTRATIGRAPHY

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Early Permian Brachiopods from five wells in the Carnarvon Basin, Western Australia (Bidgemia 1, Glenburgh 8, Burna 1, Gascoyne 1 and Ballythanna 1) are identified and illustrated. Macro faunal levels are assigned to the four earliest Permian Brachiopod zones of the Western Australian Permian (the *Lyonia lyoni*, *Trigonotreta occidentalis*, *Strophalosia irwinensis* and *Strophalosia jimbaensis* zones in ascending order) with the most complete sequence of faunas being found in Glenburgh 8. Correlation with the palynological zones (*Granulatisporites confluens*, *Pseudoreticulatispora pseudoreticulata*, *Striatopodocarpites fusus*, *Didecitriletes byroensis* and *Microbaculispora trisina* zones in ascending order) is shown to be consistent with previous outcrop–subsurface correlations.

The new genus *Cimmeriella* (Productida, Brachiopoda) is diagnosed and species from Western Australia and the Cimmerian continental fragments assigned to the genus.

Key words: Permian, Western Australia, Brachiopoda, palynology, Carnarvon Basin, new taxa.

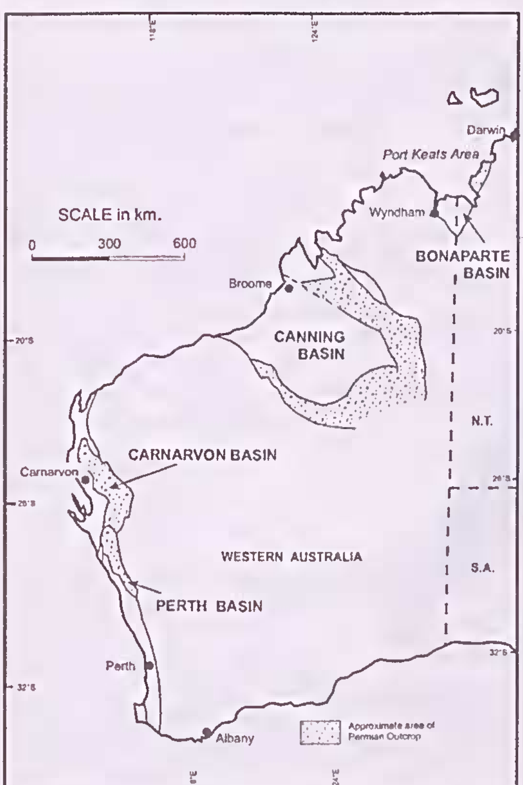


Fig. 1. Map of areas of outcrop of Permian strata in Western Australia.

EARLY PERMIAN marine strata and faunas are extensively developed in the marine basins of Western Australia. The most complete sequence of Early Permian marine faunas is to be found in the Carnarvon Basin (Fig. 1) which includes the tectonic units of the Peedamullah Shelf and Merlinleigh and Byro Sub-basins to which Permian sedimentary rocks are now largely confined (Fig. 2). Traditional correlations within the Carnarvon Basin have been based on lithostratigraphical units (Condon 1967; Hocking et al. 1987) or on faunas largely constrained by lithostratigraphy (eg. Dickins 1963; Archbold 1993). More recent work has strongly enhanced the palynological control over the sequences (Backhouse 1991, 1993, 1996, 1998; Mory & Backhouse 1997) and has integrated data from marine faunas and palynology (Archbold 1998a, 1998b, 1999) for purposes of interbasinal, transcontinental and global correlations.

The present study documents Brachiopoda from five boreholes from the onshore Carnarvon Basin (Fig. 3) and demonstrates that information from macrofossils can supplement that provided by traditional palynological investigations. Macrofossil data may, in some circumstances, provide the only data for biostratigraphy (Archbold 1988).

STRATIGRAPHICAL BACKGROUND

This study follows the interpretation of the Early Permian stratigraphy of the Carnarvon Basin, outlined by Mory & Backhouse (1997). Their study considerably altered previous interpretations of the nature and scope of the Callytharra Formation and its contact relationships with the overlying, essentially clastic sequence, known as the Wooramel Group. Units of quartz rich sandstone, previously included within the Wooramel Group, were regarded by Mory & Backhouse (1997) as being sandstone members within an enlarged definition of the Callytharra Formation.

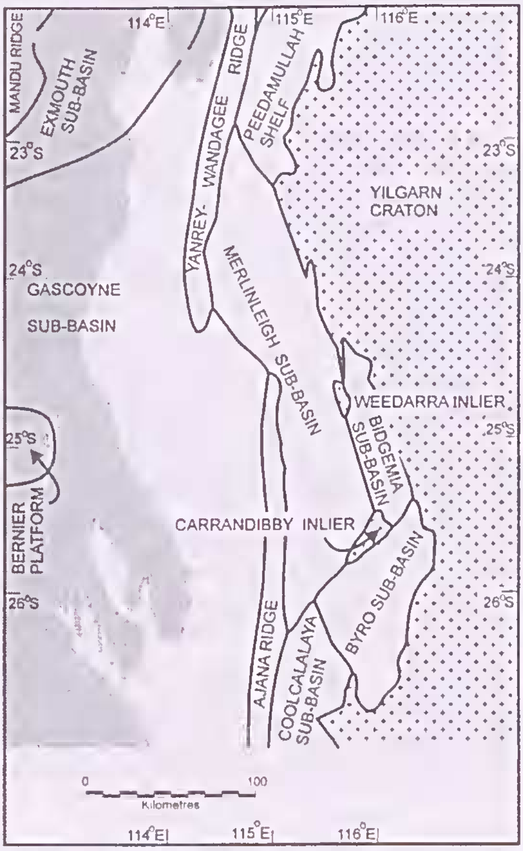


Fig. 2. Structural subdivisions of the Carnarvon Basin, Western Australia.

Complexity of outcrop patterns, problems of onlap and differing interpretations of fault patterns and other geological structures have resulted in various published interpretations of the stratigraphical relationships, sequences and nomenclature of the Callytharra and Wooramel Group. These interpretations have all been based on careful field mapping and measured stratigraphical sections. Skwarko (1993) provided a tabular summary of interpretations of the Permian stratigraphy of the Carnarvon Basin but a few remarks are made herein.

Raggatt (1936), working north of the Gascoyne River, noted the sharp contact (said to be conformable) of the Wooramel Sandstone on the ferruginous upper surface of the Callytharra Formation. The well defined boundary was also noted by Teichert (1952). Condon (1954, 1955, 1967) and Konecki et al. (1958) added substantial data concerning clastic units of the Wooramel Group resting disconformably and unconformably on a transgressive surface developed on the leached and ferruginised upper beds of the Callytharra Formation. Condon (1967) described pinnacles and rock stacks developed on the Callytharra Formation by marine erosion. These were sub-

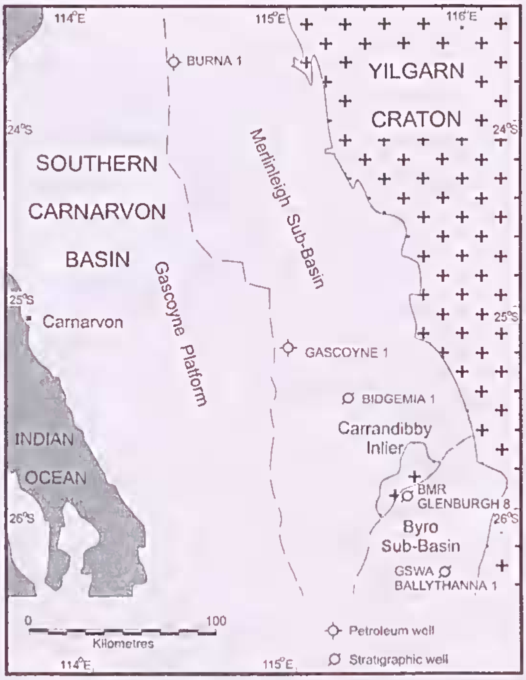


Fig. 3. Location of wells in the Merlinleigh and Byro Sub-basins.

sequently to be interpreted as tower karst features (van de Graaff et al. 1977; Hocking et al. 1987) developed during a period of subaerial leaching and erosion prior to the deposition of the Wooramel Group clastics, although Hocking (1990: 32) subsequently questioned whether much of the solution may have occurred after the deposition of the sandstone. Crostella (1995) has also questioned the evidence for the karst hiatus.

Van de Graaff et al. (1977) accepted the time break (disconformity–unconformity) at the base of the Wooramel Group but considered that sandstone and clastic units proposed southeast of the Carrandibby Inlier (Nunnery Sandstone and One Gum Formation) were variants of the Moogooloo Sandstone. Hocking et al. (1980) commented on additional 'Callytharra-type' limestone lenses, apparently equivalent in position to the Jimba Jimba Calcarenite (ie. stratigraphically above a sandstone unit and below a clastic unit) as part of the Wooramel Group. It is these 'limestone' lenses and units that Mory & Backhouse (1997), within the Byro Sub-basin and the region of the Jimba Jimba Syncline, refer to as their 'Upper Callytharra' units stratigraphically above sandstone bodies (such as the Ballythanna, Winnemia, Nunnery, One Gum, Monument and possibly Curbur Members and Formations). Hence clastic units, traditionally regarded as units of the Wooramel Group are now included within Mory & Backhouse's (1997) concept of the Callytharra Formation.

Biostratigraphically, using brachiopods but not conodonts, within Mory & Backhouse's (1997) definition of the Callytharra Formation, two fossil zones can be recognised. These are a lower 'traditional' Callytharra, *Strophalosia irwinensis* Zone (see Archbold 1993) and a higher 'traditional' Wooramel *Strophalosia jimbaensis* Zone (see Archbold 1991 and Archbold & Shi 1993). The two zones share many species and key species are required in order to recognise the younger of the two zones. The period of time between the two zones is considered by us to be a very short duration.

PREVIOUS SUBSURFACE PERMIAN BRACHIOPOD INVESTIGATIONS

Relatively few published, comprehensive, illustrated accounts of subsurface Permian brachiopod faunas are known to the present authors. Stainbrook & Madera (1941) described a well preserved fauna from Texas (USA), recovered from the Sid Richardson Coe No. 1 well, in the middle of the

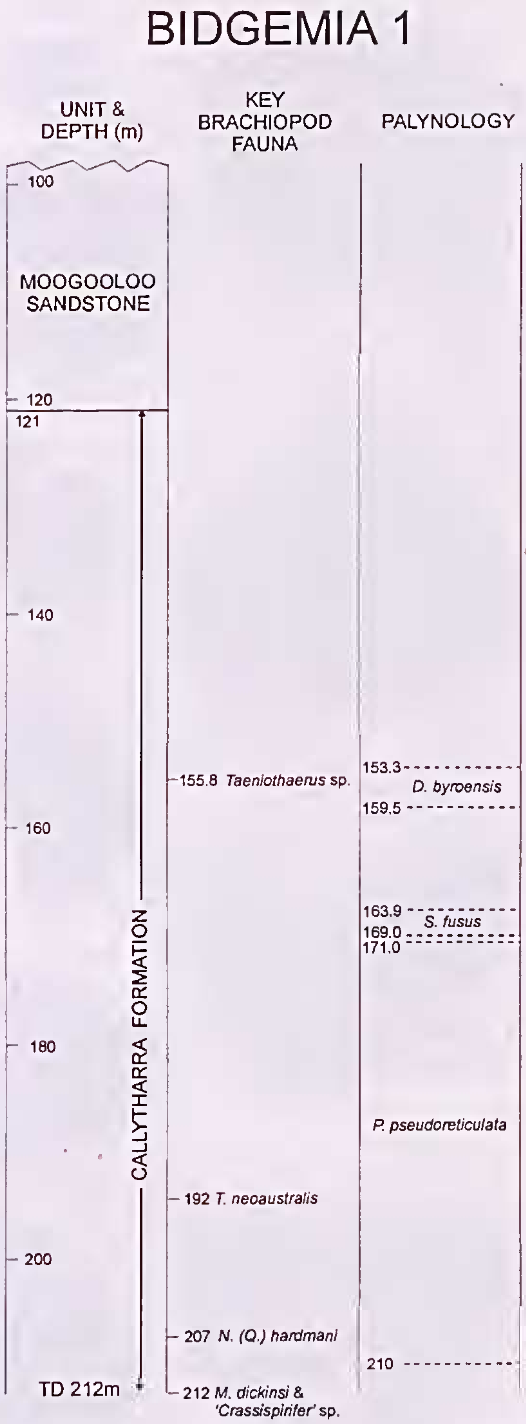


Fig. 4. Simplified well log of Bidgemia 1.

Permian Basin. The fauna was dated as 'probably low in the Word or high in the Leonard' as then understood.

The faunas from boreholes in the German part of the Zechstein Basin have been investigated and illustrated in terms of their Brachiopoda, Decapoda, conodonts, scolecodonts and species of *Estheria* (see Malzahn 1957). Those of the Polish Zechstein have been documented in a particularly well illustrated study of the Brachiopoda, Bryozoa and Bivalvia by Klapcinski (1971).

From the former Soviet Union, more numerous investigations have been published. The eastern (Baltic) end of the Zechstein Basin has received considerable attention with major studies on Lithuanian subsurface brachiopods being undertaken by Stepanov (1959) and Glushenko & Suveizdis (in Suveizdis 1975). The subsurface fauna described by those authors is fully representative of the classic outcrop fauna from comparable stratigraphical successions in England (King 1850) and Germany (Geinitz 1848). Suveizdis (1975) also included investigations on Foraminifera, Bryozoa, Bivalvia, Gastropoda, Ostracoda and palynology. A study on subsurface samples from the Arctic region of the Russian Platform that included Foraminifera, Bryozoa and Brachiopoda was published by Kalashnikov, Mikhailova & Morozova (1972). The sequence, of early Tatarian age, yielded several diagnostic, though variably preserved, genera of Brachiopoda.

A comprehensive study on the Late Carboniferous and Early Permian (Asselian) fusulinid Foraminifera, conodonts, ostracods, brachiopods and palynology from the Skosyskaya Borehole No. 4199, Tatsin Area, Rostov Region, Ukraine, was edited by Stepanov (1983). Brachiopods, were described by N. V. Glushenko, and are numerous, well preserved and age diagnostic. They are typical of those from outcrop sections of the Donets Basin (Glushenko 1975) and permit ready correlation with classic outcrop faunas of the Urals (Chernyshev 1902) and northern European Russia (Kalashnikov 1980, 1998).

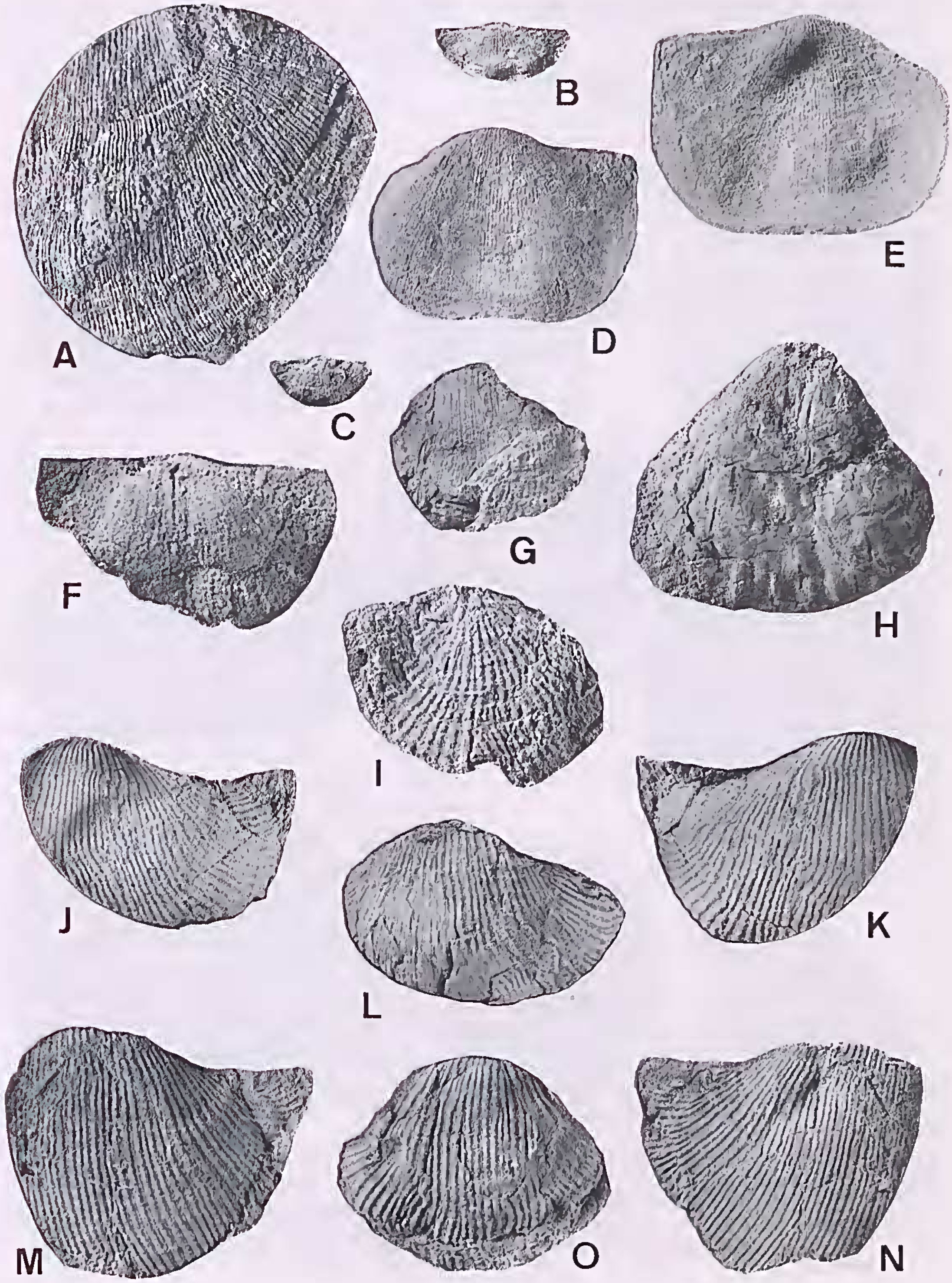
Previous Australian studies

Reports, usually consisting of lists of identifications without illustrations, of subsurface occurrences of brachiopods are relatively numerous for the Permian of Australia (eg. Dickins et al. 1961; Dickins 1965; McClung 1978). However, with the continued refinement of taxonomic precision, such lists lose their value rapidly and serve little more than to indicate which genera or families may be present in the fauna.

The comprehensive, multifaceted series of studies on the core of GSQ Eddystone 1, located in the northwestern Surat Basin near the western margin of the underlying southern Denison Trough of the Bowen Basin, Queensland, have continued to yield valuable biostratigraphical and palaeoenvironmental results (Heywood 1978; McClung 1978, 1983; McKellar 1978; Draper & McClung 1983; Palmieri 1998). This series of investigations is a good example of achieving maximum 'value for money' from a drilling programme of stratigraphic holes. The study of the brachiopods (McClung 1978, 1983) demonstrates the value of the group for subsurface biostratigraphical purposes and for providing correlation to schemes based on outcrop occurrences of macrofauna (Briggs 1998).

Apart from the classic study by Etheridge (1907) on the faunas of the Port Keats Boreholes, illustrated accounts of subsurface brachiopods from the Western Australian Permian basins are restricted to those by Foster & Waterhouse (1988) and Archbold (1988, 1995a, 1995b). Those studies enabled the recognition of the Late Permian (Dzhulfian, then called Chhidruan) from the Ashmore Block; the recognition of a new macro-

Fig. 5. Brachiopods from well cores, Ballythanna 1, Gascoyne 1, Burna 1 and Bidgemia 1. A, GSWA 00001, *Permorthotetes lindneri* Thomas, Ballythanna 1, 59.3 m, × 1. B, GSWA 00002, *Neochonetes (Sommeriella)* sp., ventral valve, Ballythanna 1, 60.3 m, × 2. C, GSWA 00003, *Neochonetes (Sommeriella)* sp., ventral valve, Ballythanna 1, 60.3 m, × 2. D, E, GSWA 00004, *Neochonetes (Sommeriella) prattii* (Davidson), ventral valve and external mould, Gascoyne 1, 476.8 m, × 1.8. F, GSWA 00005, *Neochonetes (Sommeriella)* sp., ventral valve interior, Ballythanna 1, 60.3 m, × 4. G, GSWA 00006, *Cimmeriella flexuosa* (Waterhouse), ventral valve, Burna 1, 522.45 m, × 1. H, GSWA 00007, *Taeniothaerus*? sp., ventral valve, Bidgemia 1, 155.8 m, × 2.5. I, GSWA 00008, *Cimmeriella foordi* (Etheridge), juvenile ventral valve, Ballythanna 1, 373 m, × 3. J, K, GSWA 00009, *Cimmeriella foordi* (Etheridge), ventral valve external mould and ventral valve, Gascoyne 1, 482.75 m, × 2.2. L, GSWA 00010, *Cimmeriella flexuosa* (Waterhouse), ventral valve, Gascoyne 1, 367.5 m, × 1.5. M, N, GSWA 00011, *Cimmeriella foordi* (Etheridge), ventral valve and external mould, Ballythanna 1, 357 m, × 2. O, GSWA 00012, *Cimmeriella foordi* (Etheridge), ventral valve, Gascoyne 1, 482.5 m, × 2.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faunal zone of Early Kazanian age, from the Perth Basin and refinement of the international correlation of the *Granulatisporites confluens* palynological Zone.

THE PRESENT STUDY

The palynology of the Western Australian Permian basins has been systematically documented in modern terms in a series of studies by Backhouse (1991, 1993, 1996, 1998 and in Mory & Backhouse 1997). As an adjunct to the study by Mory & Backhouse (1997) on the stratigraphy and palynology of the Carnarvon Basin, one of us (NWA) examined cores from several wells for macrofauna. This report illustrates and summarises the macrofauna data from those wells (Ballythanna 1, Bidgemia 1, Burna 1 and Gascoyne 1) and Glenburgh 8 (formerly known as BMR 8, Mt Madeline) which was investigated by NWA with C. B. Foster in 1991. The stratigraphy in the wells, as currently interpreted, is described in detail by Mory & Backhouse (1997) and the simplified well logs provided herein (with the palynological data) is taken from the detailed logs provided in that study. The brachiopod macrofauna is discussed briefly for each individual well.

Fauna from individual wells

Bidgemia 1 (Fig. 4). In an interval of the Callytharra Formation, from 192 to 212 metres, several brachiopods including *Myodelthyrium dickinsi* (Thomas), '*Crassispirifer*' sp., *Neospirifer (Quadrospira) hardmani* (Foord) and *Trigonotreta neoaustralis* (Archbold & Thomas) occur in an interval with the *Pseudoreticulatispora pseudoreticulata* palynological Zone (see Figs 5 and 12 for illustrations of species present). They indicate that the Lower part of the Callytharra Formation, as defined by Mory & Backhouse (1997), and the *Strophalosia irwinensis* brachiopod Zone as defined by Archbold (1998b), is present at these levels.

From higher (155.8 m) in the Callytharra Formation, at the level of the *Dibecitriletes byroensis* palynological subzone, a small specimen, with coarse ventral spine bases, of *Taeniothaerus* sp.

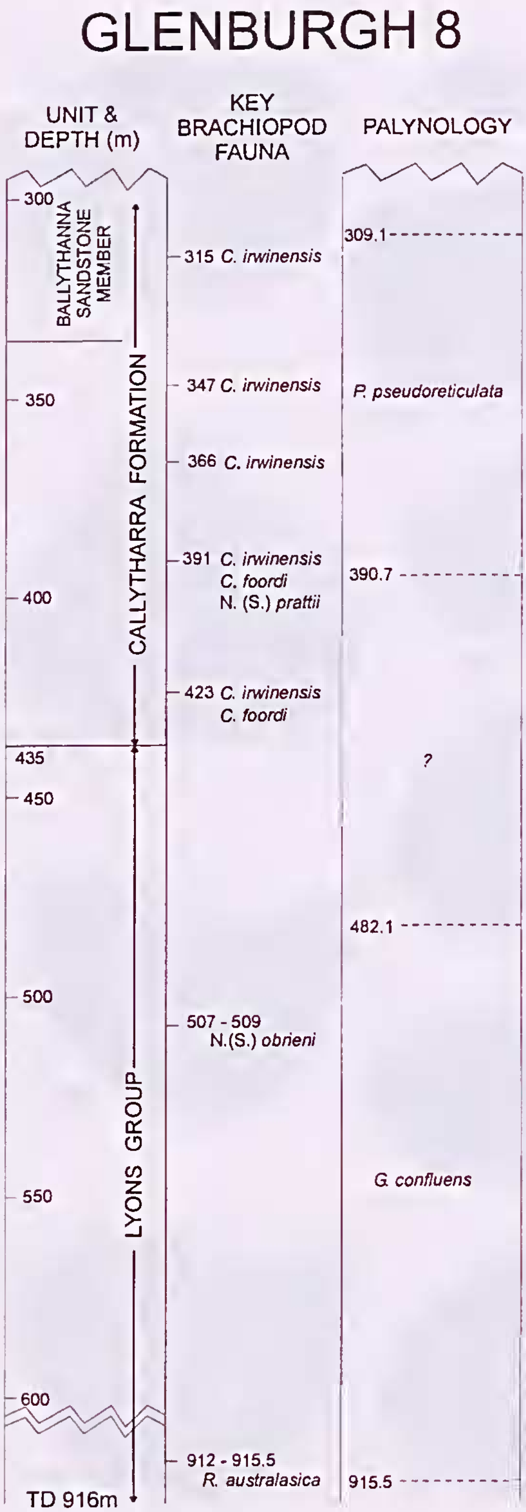


Fig. 6. Simplified well log of Glenburgh 8. Palynological data from Mory & Backhouse (1997) and supplemented by that of C. B. Foster (pers. comm. 24.viii.1992).

that recalls *Reedoconcha*? sp. (Archbold & Shi 1993: fig. 3A) from the Jimba Jimba Calcarenite, was noted. This level in Bidgemia 1 may represent the Upper Callytharra Formation as defined by Mory & Backhouse (1997) and hence the *Strophalosia jimbaensis* brachiopod Zone.

Glenburgh 8 (Fig. 6). Brachiopods from this well were listed by Dickins (1967) and, in part, reported on by Archbold (1995) who noted the occurrence of equivalents of the *Lyonia lyoni* and *Trigonotreta occidentalis* brachiopod zones as represented by *Rhynchopora australasica* Archbold

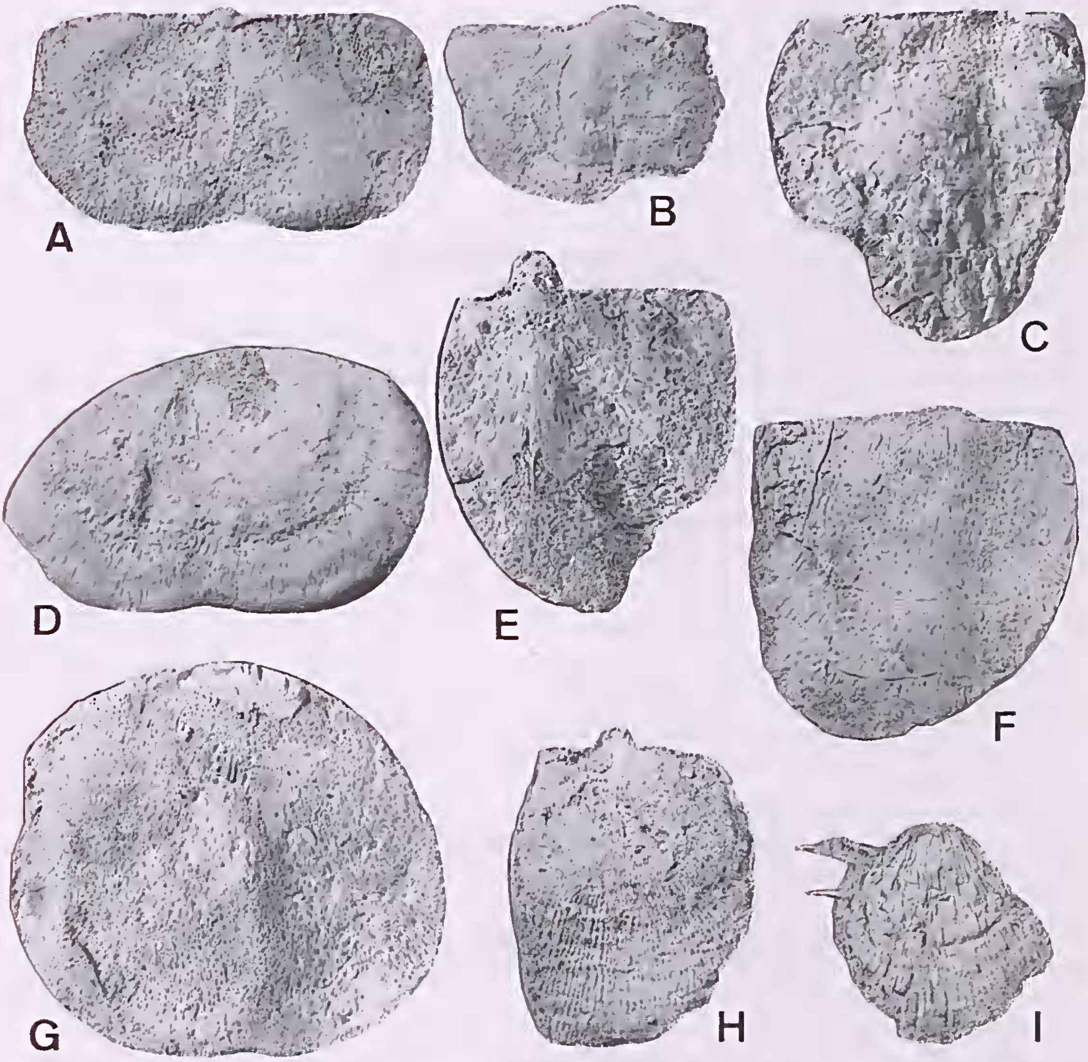


Fig. 7. Brachiopods from Glenburgh 8. A, *Neochonetes (Sommeriella)* cf. *cockbaini* Archbold, dorsal valve interior, 162 m, × 1.8. B, *Neochonetes (Sommeriella)* sp., ventral valve, 161.54 m, × 2. C, E, *Taeniothaerus*? sp., dorsal valve external mould and dorsal valve exterior, 162 m, × 1. D, *Neochonetes (Sommeriella)* cf. *cockbaini* Archbold, dorsal valve interior, 162 m, × 1.5. F, *Taeniothaerus* sp., dorsal valve exterior, 163 m, × 1. G, *Taeniothaerus* sp., 163.5 m, × 1. H, *Costatumulus irwinensis* (Archbold), dorsal valve interior, 310 m, × 2. I, *Costatumulus irwinensis* (Archbold), ventral valve exterior, 338 m, × 2.

and *Neochonetes (Sommeriella) obrieni* Archbold respectively (Archbold 1998b). The present report provides identification of typical brachiopods from the Lower Callytharra Formation *Strophalosia irwinensis* brachiopod Zone which coincides in large part with the *Pseudoreticulatisporites pseudoreticulata* palynological Zone. From 315 m to 423 m brachiopods include *Costatumulus irwinensis* (Archbold), *Cimmeriella foordi* (Etheridge) and *Neochonetes (Sommeriella) prattii* (Davidson) as indicated in Fig. 6 and illustrated in Fig 7.

Glenburgh 8 is of considerable interest because of a brachiopod fauna from Core 6 (160.6–163.7 m depth; see Fig. 7 for illustrations) which includes *Neochonetes (Sommeriella)* cf. *cockbaini* Archbold and *Aulosteges* sp. (cf. *Aulosteges* sp. Archbold 1991: fig. 1E from the basal One Gum Formation = Ballythanna Sandstone). As interpreted by Mory & Backhouse (1997), Core 6 of Glenburgh 8 represents the uppermost Callytharra Formation and is likely to be a correlative with the Jimba Jimba Calcarenite. No palynological data is available from Core 6 but the depth of the core is likely to correlate with the top of the *Striatopodocarpites fusus* Zone or the base of the *Microbaculispora trisina* Zone.

Foraminifera from Glenburgh 8 were described and illustrated by Belford (1968). Palynological data from Mory & Backhouse (1997) were supplemented for this study by determinations by C. B. Foster (pers. comm. 24.viii.1992) for the depths of 482.1 m and 915.5 m.

Burna 1 (Fig. 8). Brachiopods are not common in the well. Two occurrences from the Cordalia Formation, *Cimmeriella flexuosa* (Waterhouse) and *Neospirifer (Quadrospira) hardmani* (Foord), are consistent with a correlation with the Jimba Jimba fauna (the *Strophalosia jimbaensis* Zone). The record of *Cimmeriella flexuosa* at 522.45 m comes from the *M. trisina* Zone whereas the *N. (Q.) hardmani*, at 574.9 m, is probably from the *S. fusus* Zone. Specimens are illustrated in Figs 5 and 12.

Gascoyne 1 (Fig. 9). This well includes a complete section through the Callytharra Formation, including the Winnemia Sandstone Member. From below the Winnemia Sandstone, *Neochonetes (Sommerilla) prattii* (Davidson) and *Cimmeriella foordi* (Etheridge), both typical of the *Strophalosia irwinensis* Zone, are known. Immediately above the Sandstone, at 345.4 m and 401.1 m, respectively, *Costatumulus irwinensis* (Archbold) and *Elivina hoskingae* Archbold & Thomas occur and also probably represent the *Strophalosia irwinensis* Zone (*E. hoskingae* is unknown from the Jimba Jimba fauna). At 367.5 m, the occurrence of *C. flexuosa* (Waterhouse), from high in the *S. fusus* Zone, indicates the *Strophalosia jimbaensis* Zone. Specimens are illustrated in Figs 5, 10 and 12.

Ballythanna 1 (Fig. 11). This well also intersected a complete section of the Callytharra Formation including the Ballythanna Sandstone Member

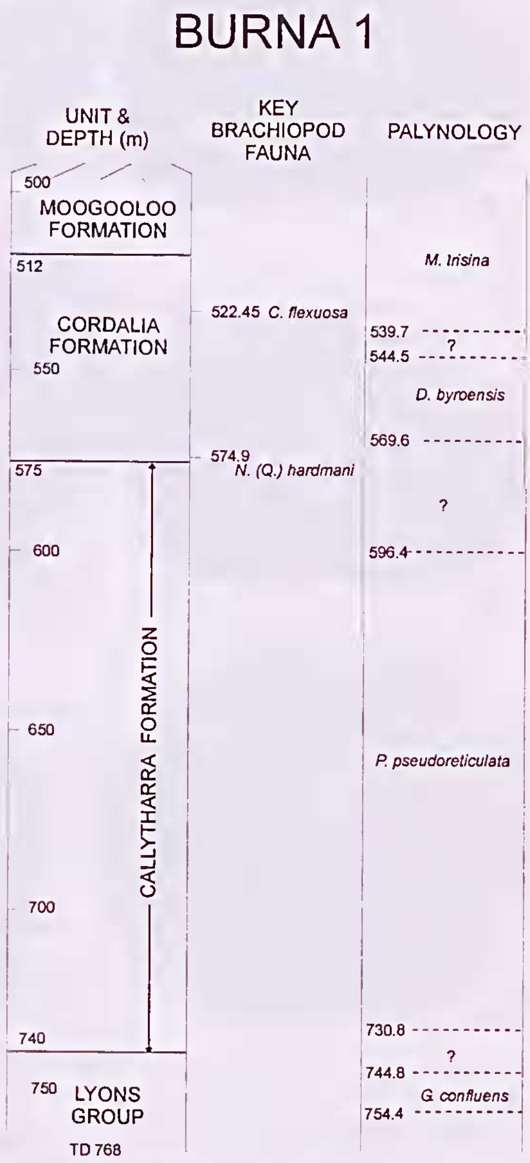


Fig. 8. Simplified well log of Burna 1.

(Mory 1996). From below the sandstone typical brachiopods of the *Strophalosia irwinensis* Zone occur including *Cimmeriella foordi* (Etheridge), *Costatumulus irwinensis* (Archbold), *Cyrtella* sp., *Trigonotreta neoaustralis* Archbold & Thomas and *Spirelytha fredericksi* Archbold & Thomas. These occur with the *P. pseudoreticulata* palynozone and are illustrated in Figs 5, 10 and 12.

From above the Ballythanna Sandstone, associated with the top of the *S. fusus* palynozone, brachiopods including *Permorthotetes lindneri* Thomas may indicate the Jimba Jimba fauna, but preservation is variable and the key species of *Strophalosia* and *Cimmeriella* are absent.

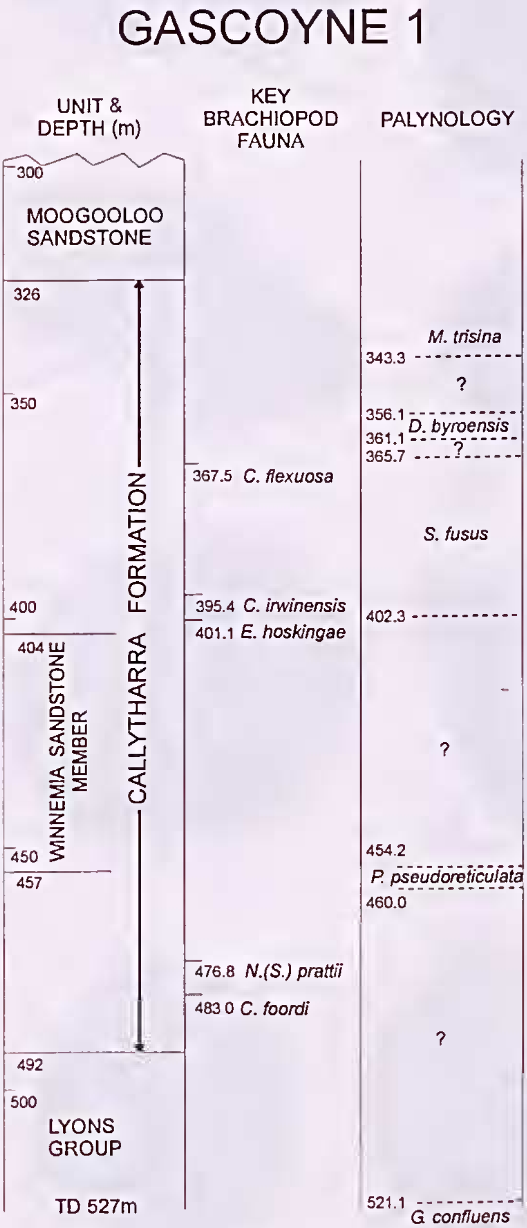


Fig. 9. Simplified well log of Gascoyne 1.

SUMMARY AND CONCLUSIONS

Macrofaunal levels from five wells (Bidgemia 1, Glenburgh 8, Burna 1, Gascoyne 1 and Ballythanna 1) in the Merlinleigh and Byro Sub-basins of the Carnarvon Basin are summarised in Fig. 13. While the quality and abundance of macrofaunal data varies from well to well (as with palynological data), the macrofaunas can be assigned to macrofaunal brachiopod zones developed in outcrop sequences and can be directly matched to the subsurface palynological zones discussed and refined in Mory & Backhouse (1997). The results of this study indicate that the investigation of cores through marine Permian sequences for macrofossil data provides useful information for biostratigraphical purposes. Hence such studies should be a normal part of stratigraphical drilling programmes in order to maximise the benefits of such programmes.

SYSTEMATIC PALAEONTOLOGY

Order PRODUCTIDA
Sarycheva & Sokolskaya 1959

Suborder PRODUCTIDINA Waagen 1883

Superfamily LINOPRODUCTOIDEA Stehli 1954

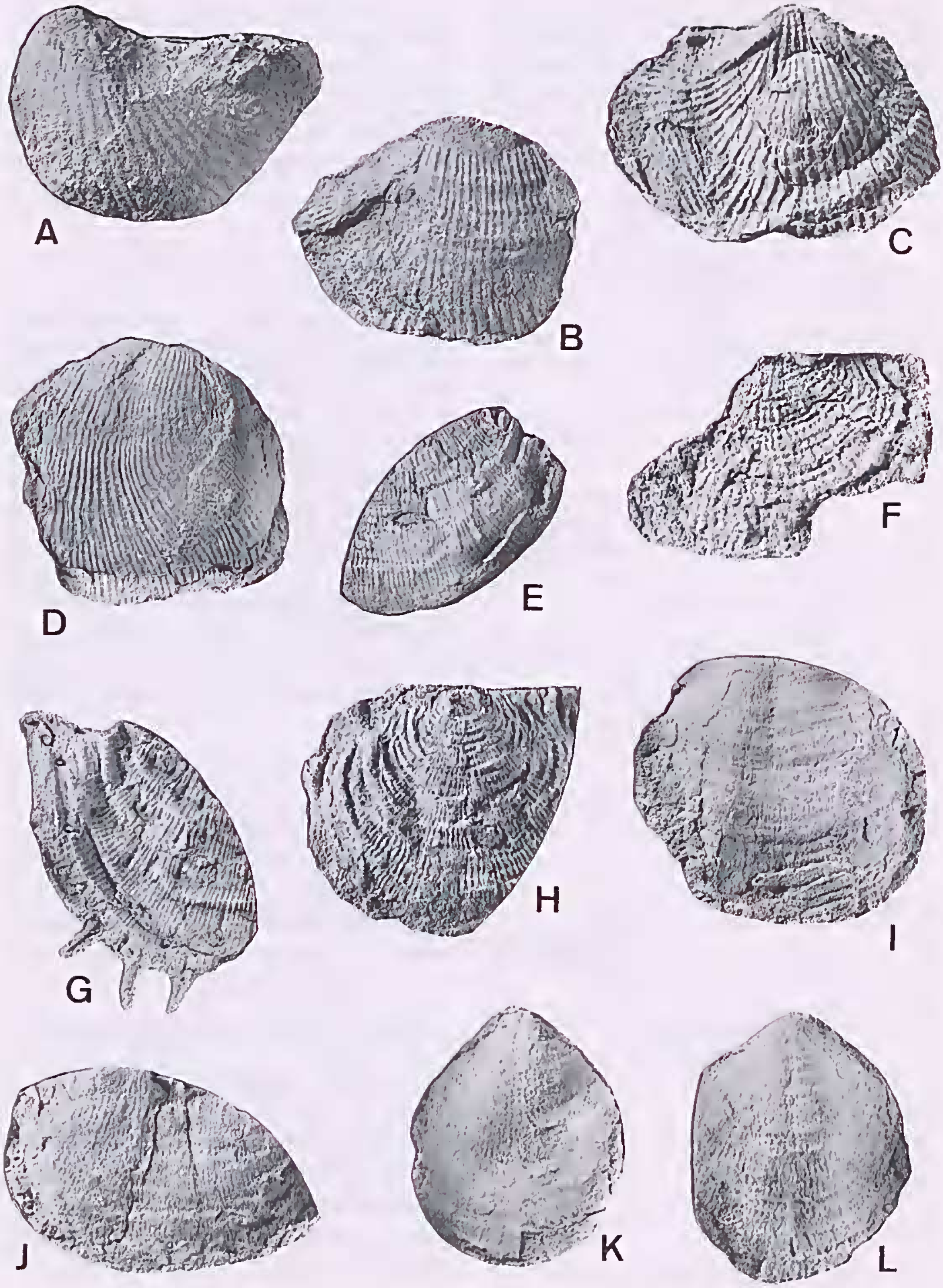
Family LINOPRODUCTIDAE Stehli 1954

Subfamily LINOPRODUCTINAE Stehli 1954

Genus **Cimmeriella** gen. nov.

Type species. Productus tenuistriatus De Verneuil (?) var. *foordi* Etheridge (1903), from the Sterlitamakian (Late Sakmarian) Lower Callytharra Formation, Carnarvon Basin, Western Australia; revised and illustrated by Archbold (1983).

Etymology. Named from the Cimmerian marine province of the Permian from which many of the species of the genus are to be found.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Diagnosis. Small to medium sized, globose Linoproductinae with relatively coarse costellae and wide intercostal valleys. Ventral posterior adductor scars deeply impressed; anterior diductor scars weakly striate. Dorsal median septum arises close to cardinal process. Rugae weak or absent, spines restricted to hinge region of ventral valve.

Discussion. Species of *Cimmeriella* gen. nov. have traditionally been assigned to *Stepanoviella* Zavodovskiy (1960) or to *Globiella* Muir-Wood & Cooper (1960). *Stepanoviella*, type species *S. paracurvata* Zavodovsky (1960), is characterised by extremely fine costellae, as illustrated in the accounts by Zavodovskiy (1960: pl. 81, figs 1–7), Zavodovskiy & Stepanov (1970: pl. 89, figs 1–8; pl. 90, figs 1–3) and Grigoryeva et al. (1977: pl. 27, figs 5–8) and possesses ventral spines of two types, fine dorsal spines and is restricted to species from the Kazanian–Tatarian of northeastern Siberia (Grigoryeva et al. 1977).

Globiella Muir-Wood & Cooper (1960), type species *Productus hemisphaerium* Kutorga (1844: 99, pl. 10, figs 2a–c), includes a group of globose species from the Kazanian of European Russia that have been long studied. Classic accounts of the type species, or closely related species, include those of Keyserling (1854: 102, pl. 2, figs 16, 17), Golovkinskiy (1868: 361, pl. 3, figs 1–3), Geinitz (1861: 102, pl. 18, figs 28, 29), Nechaev (1894: 145+, pl. 4, figs 1a–c, 2a–c), Frech (1901: pl. 63, fig. 7; pl. 64, fig. 13) and Nechaev (1911: 26+, pl. 1, figs 1a–9b; pl. 2, figs 1–16; pl. 3, fig. 1). Modern accounts are those of Muir-Wood & Cooper (1960), Grigoryeva (1962), Grigoryeva et al. (1977) and Gubareva (1998). Reports of this species group, herein treated as true *Globiella*, described from the Late Permian of the Trans-Caucasas (Armenia) by various authors, were shown to be erroneous by Stoyanov (1916). Through the courtesy of N. L. Fomicheva, the Director of the Geological and

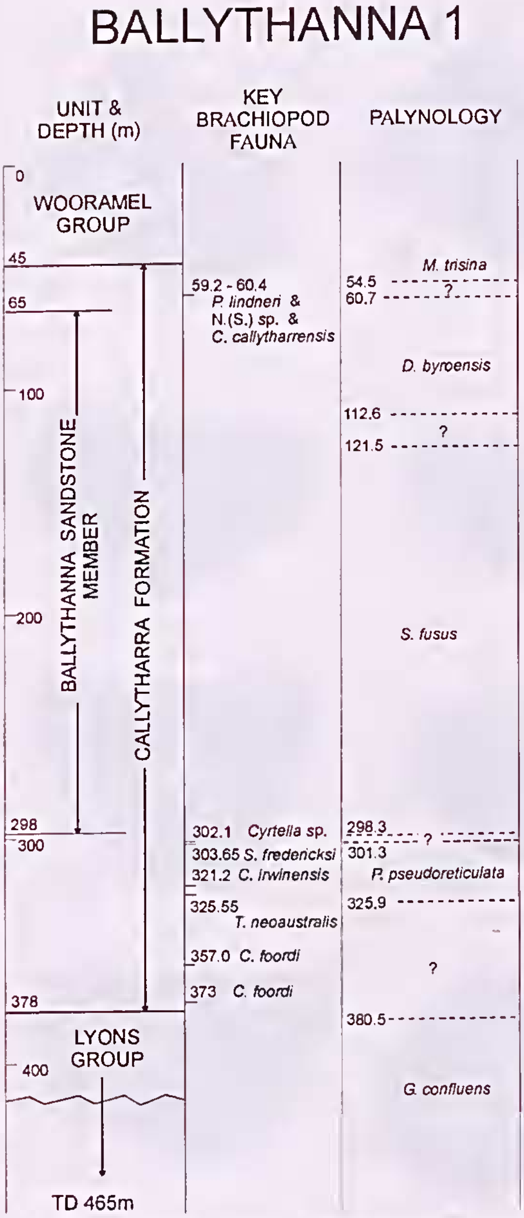
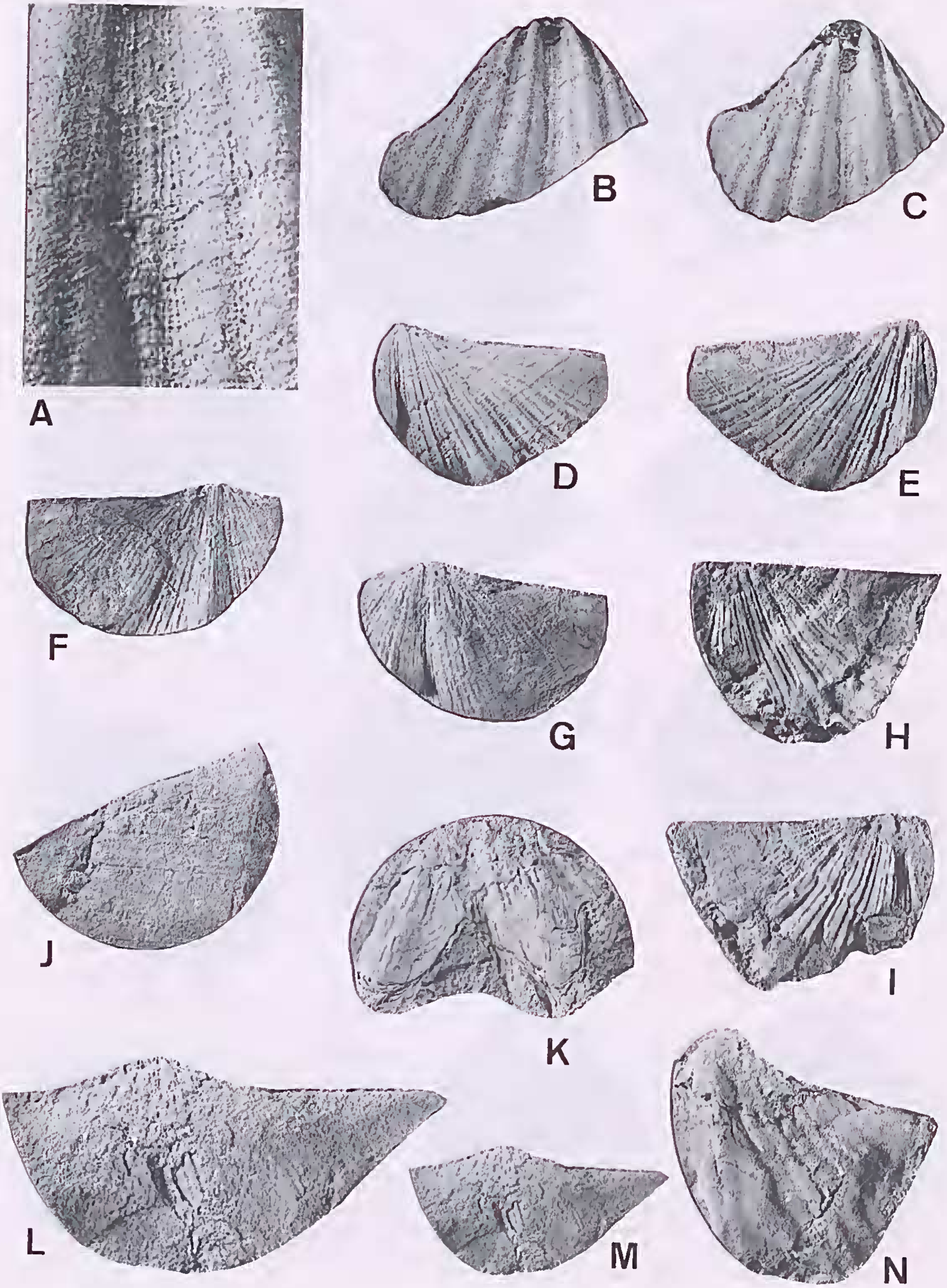


Fig. 11. Simplified well log of Ballythanna 1.

Fig. 10. Brachiopods from Ballythanna 1 and Gascoyne 1. A, GSWA 00013, *Cimmeriella foordi* (Etheridge), ventral valve, Ballythanna 1, 373 m, ×2.8. B, GSWA 00014, *Cimmeriella foordi* (Etheridge), ventral valve, Ballythanna 1, 357 m, ×2.4. C, GSWA 00015, *Cimmeriella foordi* (Etheridge), ventral valve, Ballythanna 1, 373 m, ×2.8. D, GSWA 00016, *Cimmeriella foordi* (Etheridge), ventral valve, Gascoyne 1, 482.5 m, ×1.6. E, G, GSWA 00017, *Costatumulus irwinensis* (Archbold), ventral valve internal mould and ventral external mould, Gascoyne 1, 395.4 m, ×1.6. F, GSWA 00018, *Callytharrella callytharrensis* (Prendergast), ventral? valve, Ballythanna 1, 60.2 m, ×4. H, GSWA 00019, *Costatumulus irwinensis* (Archbold), dorsal external mould, Ballythanna 1, 321.2 m, ×1.6. I, GSWA 00020, *Spirelytha fredericksi* Archbold & Thomas, ventral valve, Ballythanna 1, 303.65 m, ×1.8. J, GSWA 00021, *Costatumulus irwinensis* (Archbold), ventral valve internal mould, Ballythanna 1, 303.65 m, ×1.5. K, L, GSWA 00022, *Spirelytha fredericksi* Archbold & Thomas, ventral valve external mould and counterpart, Ballythanna 1, 303.65 m, ×2.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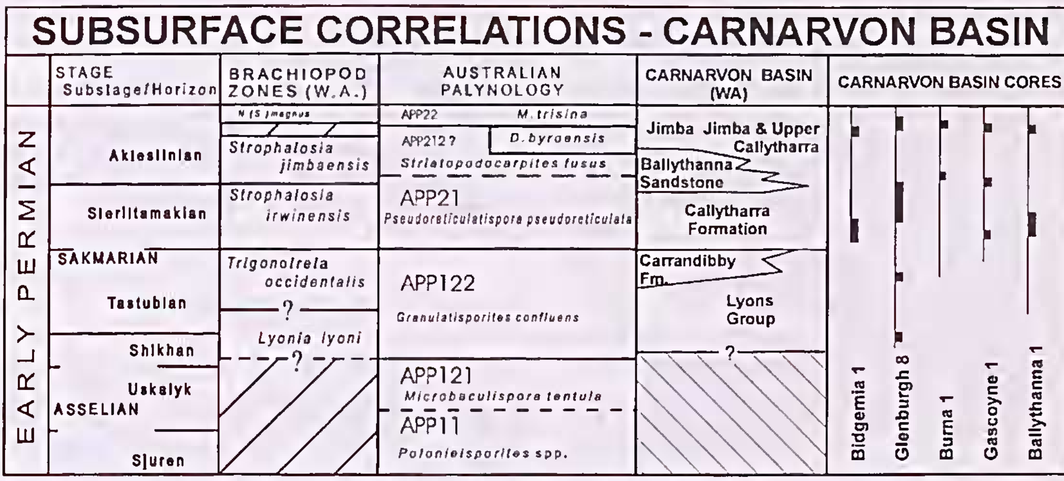

Fig. 13. Correlation of cores with palaeontological and lithological schemes. Recovered macrofauna indicated by thickening of lines. Interpretation of stratigraphy from Mory & Backhouse (1997).

Mineralogical Museum, Kazan University, one of us (NWA) in 1998, was able to examine Nechaev's 1894 specimens (see Fomicheva et al. 1998 for details of Nechaev's collection) and large collections from the Kazanian of the Russian Platform. Examination of large suites of specimens of the Russian species indicated that species from the early Permian of the Gondwanan margin were close to, but distinct from, *Globiella*.

Species and reports assigned to *Cimmeriella* (see below) indicate a group of species with relatively coarse costellae and distinct intercostal valleys unlike those of *Globiella*. Mature *Globiella* is characterised by deeply impressed anterior diductor scars that are markedly striate unlike those of *Cimmeriella* which at maturity are only feebly striate. Other differences between the genera include the nature of the posterior adductor scars which are divided in *Cimmeriella* and the morphology of the dorsal medium septum which extends further posteriorly in *Cimmeriella* than in *Globiella*. *Globiella* possesses a thicker dorsal valve than *Cimmeriella*, the dorsal valve of which is very delicate and liable to fragment, no doubt accounting for the rarity of preserved dorsal valves of the latter genus.

Species and reports assigned to Cimmeriella

1. *Productus tenuistriatus* De Verneuil (?) var. *foordi* Etheridge (1903: 19, pl. 1, figs 3, 4; pl. 3, fig. 22). Sterlitamakian, Western Australia.
2. *Stepanoviella flexuosa* Waterhouse (1970: 45, pl. 14, figs 1–8, 15–16). Aktastinian, Western Australia.
3. *Productus cora*: Broili (1915: pl. 21, figs 4a–b). Letti (Leti) Island, Indonesia, Aktastinian?
4. *Productus cora*: Broili (1916: pl. 1, figs 14, 15; pl. 2, figs 1–3). Bitauni, Indonesian Timor, Artinskian.

Fig. 12. Brachiopods from Gascoyne 1, Bidgemia 1, Burna 1 and Ballythanna 1. A, B, C, GSWA 00023, *Elivina hoskingae* Archbold & Thomas, ventral micro-ornament × 8, ventral valve anterior and ventral views, Gascoyne 1, 401.1 m, × 2. D, E, GSWA 00024, *Trigonotreta neoaustralis* Archbold & Thomas, ventral valve and external ventral mould, Bidgemia 1, 192 m, × 1. F, G, GSWA 00025, *Neospirifer (Quadrospira) hardmani* (Foord), ventral external mould and ventral valve, Bidgemia 1, 207 m, × 1. H, I, GSWA 00026, *Trigonotreta neoaustralis* Archbold & Thomas, ventral external mould and ventral valve, Ballythanna 1, 325.55 m, × 1.2. J, GSWA 00027, *Myodelthyrium dickinsi* (Thomas), ventral interarea, Bidgemia 1, 212 m, × 1. K, GSWA 00028, *Neospirifer (Quadrospira) hardmani* (Foord), ventral valve, Burna 1, 574.9 m, × 1. L, M, GSWA 00029, '*Crassispirifer*' sp., ventral valve, Bidgemia 1, 212 m, × 2 and × 1. N, GSWA 00030, *Cyrtella* sp., dorsal valve internal mould, Ballythanna 1, 302.1 m, × 1.2.

5. *Linoproductus cora*: Shimizu (1966: 407, pl. 2, figs 16–23). Several localities, East Timor, Artinskian.
6. *Globiella* sp. Shi & Waterhouse (1991: 33, fig. 2[23–25]). Perak, west Malaysia, Sterlitamakian–Aktastinian.
7. *Stepanoviella hemisphaerium*: Nie et al. (1993: pl. 1, figs 5–8). Western Yunnan, Sterlitamakian.
8. *Stepanoviella mucronata* Fang (1994: 268, pl. 1, figs 10–13). Baoshan Region, Western Yunnan, Sterlitamakian.
9. *Globiella youwangensis* Shi et al. (1996: 92, fig. 4F). Baoshan Region, Western Yunnan, Sterlitamakian.
10. *Stepanoviella gracilis* Ching (in Ching et al. 1977: 244, pl. 1, figs 10–12). Jilong Formation, Tibet, Sterlitamakian.
11. *Stepanoviella flexuosa*: Jing & Sun (1981: 140, pl. 5, figs 7, 8). Poindo Series, Tibet, Sakmarian.
12. *Globiella qiangduoensis* Sun (1991: 234, pl. 3, figs 28–32). Northwestern Tibet, Sakmarian.
13. *Globiella* cf. *rossiae*: Angiolini (1995: 174, pl. 1, figs 14–19). Karakorum, Sterlitamakian–Aktastinian
14. *Productus* cf. *waagenianus*: Merla (1934: 226, pl. 20, figs 45–47). Rimu, North Karakorum, Artinskian?

Reports of '*Stepanoviella*' from Afghanistan (eg. Termier & Termier 1971) cannot be confirmed as the material has not been fully described or illustrated. *Stepanoviella rossiae* Fantini Sestini (1966: 28, pl. 4, figs 1a–b) from North Iran is excluded from *Cimmeriella* in view of the low convexity of the Iranian species and very fine costellae. The *Globiella*? *rossiae* of Grunt & Dmitriev (1973: 107, pl. 7, figs 6–8) from the Early Artinskian of the Pamirs, is characterised by distinct, numerous, fine rugae on the ventral valve that are unlike those of true *Cimmeriella* and hence the report is excluded from the new genus. Peninsula Indian species, referred to *Globiella* by Archbold (1983), are now transferred to *Bandoproductus* Jing & Sun (1981) due to the presence of ventral spines (Archbold et al. 1996).

Globiella costellata Shi & Waterhouse (1996: 98, pl. 15, figs 9–24), from the Sakmarian of the Yukon Territory, Canada, appears to be a true *Cimmeriella* on the basis of its costellae and shell outline and hence indicates the bipolar distribution of the genus during the Early Permian.

Productus ufensis Fredericks (1915: 51, pl. 2, fig. 13; pl. 4, figs 3–6), from the Sakmarian of the Sarva River and other localities in the Ural Mountains, approaches *Cimmeriella* in terms of its costal characteristics but possesses a narrower, higher ventral umbo.

Productus lutkewitschi Stepanov (1936: 121, pl. 1, figs 5a–c; 1937: 135, figs 1a–c) from the Ufimian of Spitzbergen possesses strongly developed rugae on the posterior of the ventral valve and hence is excluded from the genus *Cimmeriella*.

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REFERENCES

ANGIOLINI, L., 1995. Permian brachiopods from Karakorum (Pakistan). Pt 1 (with appendix). *Rivista Italiana de Paleontologia e Stratigrafia* 101(2): 165–214, pls 1–10.

ARCHBOLD, N. W., 1983. Studies on Western Australian Permian brachiopods 3. The family Linoproductidae Stehli 1954. *Proceedings of the Royal Society of Victoria* 95(4): 237–254.

ARCHBOLD, N. W., 1988. Permian Brachiopoda and Bivalvia from Sahul Shoals No. 1, Ashmore Block, Northwestern Australia. *Proceedings of the Royal Society of Victoria* 100: 33–38.

ARCHBOLD, N. W., 1991. Studies on Western Australian Permian brachiopods 10. Faunas from the Wooramel Group, Carnarvon Basin. *Proceedings of the Royal Society of Victoria* 103: 55–66.

ARCHBOLD, N. W., 1993. A zonation of the Permian brachiopod faunas of Western Australia. In *Gondwana Eight. Assembly, evolution and dispersal*, R. H. Findlay, R. Unrug, M. R. Banks & J. J. Veevers, eds, A. A. Balkema, Rotterdam, Brookfield, 313–321.

ARCHBOLD, N. W., 1995a. Ufimian (early Late Permian) brachiopods from the Perth Basin, Western Australia. *Memoir of the Australasian Association of Palaeontologists* 18: 153–163.

ARCHBOLD, N. W., 1995b. Studies on Western Australian Permian brachiopods 12. Additions to the Late Asselian–Tastubian faunas. *Proceedings of the Royal Society of Victoria* 107(2): 95–112.

ARCHBOLD, N. W., 1998a. Marine biostratigraphy and correlation of the Western Australian Permian basins. In *The sedimentary Basins of Western Australia 2*, P. G. Purcell & R. R. Purcell, eds, Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 1998: 141–151.

ARCHBOLD, N. W., 1998b. Correlations of the Western Australian Permian and Permian ocean circulation patterns. *Proceedings of the Royal Society of Victoria* 110(1/2): 85–106.

ARCHBOLD, N. W., 1999. Permian Gondwanan correlations: the significance of the western Australian marine Permian. *Journal of African Earth Sciences* 29(1): 62–75.

ARCHBOLD, N. W., SHAH, S. C. & DICKINS, J. M., 1996. Early Permian brachiopod faunas from Peninsular India: their Gondwanan relationships. *Historical Biology* 11: 125–135.

ARCHBOLD, N. W. & SHI, G. R., 1993. Aktastinian (Early Artinskian, Early Permian) brachiopods from the Jimba Jimba Calcarenite, Wooramel Group, Carnarvon Basin, Western Australia. *Proceedings of the Royal Society of Victoria* 105(2): 187–202.

BACKHOUSE, J., 1991. Permian palynostratigraphy of the Collie Basin, Western Australia. *Review of Palaeobotany and Palynology* 67: 237–314.

BACKHOUSE, J., 1993. Palynology and correlation of Permian sediments in the Perth, Collie and Officer basins, Western Australia. *Report of the Geological Survey of Western Australia* 34: 111–128.

BACKHOUSE, J., 1996. Palynology. In *GSWA Ballythanna 1 Well Completion report*, A. J. Mory, compiler, *Record of the Geological Survey of Western Australia* 1996/7: 17–23.

BACKHOUSE, J., 1998. Palynological correlation of the Western Australian Permian. *Proceedings of the Royal Society of Victoria* 110(1/2): 107–114.

BELFORD, D. J., 1968. Permian Foraminifera from BMR Bores 6, 7, 8 and 9, Western Australia. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics* 80: 1–12, 3 pls.

BRIGGS, D. J. C., 1998. Permian Productidina and Strophalosiidina from the Sydney–Bowen Basin and New England Orogen: systematics and biostratigraphic significance. *Memoir of the Association of Australasian Palaeontologists* 19: 1–258.

BROILI, F., 1915. Permische Brachiopoden der Insel Letti. *Jaarboek van het Mijnwezen in Nederlandsch Oost-Indie* 43(1): 187–207, pl. 21.

BROILI, F., 1916. Die Permischen brachiopoden von Timor. *Palaontologie von Timor* 7(12): 1–104, 13 pls.

CHERNYSHEV, F. N. (TSCHERNYSCHEW, T. N.), 1902. Verkhnekamenougol'nye brakhiopody Urala i Timana. *Trudy Geologicheskago Komiteta* 16(2): 1–749 + atlas.

CHING, Y.-K. (JIN, Y.-G.), LIANG, X.-L. & WEN, S.-S., 1977. Additional material of animal fossils from the Permian deposits on the northern slope of Mount Qomolangma Feng. *Scientia Geologica Sinica* 7(3): 236–249, 2 pls.

CONDON, M. A., 1954. Progress report on the stratigraphy and structure of the Carnarvon Basin, Western Australia. *Report of the Bureau of Mineral Resources, Geology and Geophysics* 15: 1–163, pls 1–3.

CONDON, M. A., 1955. Minilya—4-Mile Geological Series. Explanatory Notes. *Bureau of Mineral Resources, Geology and Geophysics, Note Series No.* 4: 1–19.

CONDON, M. A., 1967. The Geology of the Carnarvon Basin, Western Australia. Part 2: Permian Stratigraphy. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics* 77: i–viii, 1–191, 2 charts.

CROSTELLA, A., 1995. Structural evolution and hydrocarbon potential of the Merlinleigh and Byro Sub-basins, Carnarvon Basin, Western Australia. *Report of the Geological Survey of Western Australia* 45: 1–36.

DICKINS, J. M., 1963. Permian pelecypods and gastropods from Western Australia. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics* 63: 1–203.

DICKINS, J. M., 1965. Permian fossils from the Beagle Ridge Bores BMR 10 and 10A. *Report of the Bureau of Mineral Resources, Geology and Geophysics* 80: 36.

DICKINS, J. M., 1967. Permian macrofossils from bores BMR 8 and BMR 9. *Report of the Bureau of Mineral Resources, Geology and Geophysics* 108: 14–19.

DICKINS, J. M., MCTAVISH, R. A. & BALME, B. E., 1961. The Beagle Ridge Bore. *Australasian Oil & Gas Journal* 7: 20–21.

DRAPER, J. J. & MCCLUNG, G. R., 1983. Sedimentation and depositional environments of the Permian sequence in GSQ Eddystone 1, Denison Trough, Queensland. *Geological Survey of Queensland Publication* 384: 1–41.

ETHERIDGE, R. JNR, 1903. Descriptions of Carboniferous fossils from the Gascoyne District, Western Australia. *Bulletin of the Geological Survey of Western Australia* 10: 1–41, pls 1–6.

ETHERIDGE, R. JNR, 1907. Official contributions to the Palaeontology of South Australia, No. 19. Fossils of the Port Keats Bore, thirty miles north of Fossil Head, Treachery Bay. *Proceedings of the Parliament of South Australia, House of Assembly, Parliamentary Paper* 54: 11–15, pls 8, 12.

FANG, R.-S., 1994. The discovery of cold-water brachiopod *Stepanoviella* fauna in Baoshan region and its geological significance. *Yunnan Geology* 13(3): 264–277, pls 1–3.

FANTINI SESTINI, N., 1996. Brachiopods from Geirud Formation, Member D (lower Permian). *Rivista Italiana di Paleontologia e stratigrafia* 72(1): 9–50, pls 2–5.

FOMICHEVA, N. L., SHILOVSKII, O. P. & SMYSHLYAVKINI, E. O., 1998. *Katalog Orginalov. Permskaya Sistema* 2: 1–98. Izdatel'stvo Kazanskogo Universiteta.

FOSTER, C. B. & WATERHOUSE, J. B., 1988. The

Granulatisporites confluens Oppel–zone and Early Permian marine faunas from the Grant Formation on the Barbwire Terrace, Canning Basin, Western Australia. *Australian Journal of Earth Sciences* 35: 135–157.

Frech, F., 1902. *Lethaea geognostica oder beschreibung und abbildung der fur die Gebirgs-Formationen bezeichnendsten Versteinerungen*. 1. Theil. Lethaea palaeozoica. 2. Band. & Atlas. Stuttgart, E. Schweizerbart'sche Verlagshandlung (E. Nagale).

Fredericks, G. N., 1915. Paleontologicheskiya Zametki. 1. K' poznaniyu verkhne-kamennougol'nykh' i Artinskikh *Productus*. *Trudy Geologicheskago Komiteta, Novaya Seriya* 103: 1–63, pls 1–5.

Geinitz, H. B., 1848. *Die Versteinerungen des Zechsteingebirges und Rothliegenden oder des Permischen Systemes in Sachsen. Heft 1. Die Versteinerungen des deutschen Zechsteingebirges*. Dresden und Leipzig, Arnoldische Buchhandlung, 26 pp, 8 pls.

Geinitz, H. B., 1861. *Dyas oder die Zechsteinformation und das Rothliegende. Heft 1. Die animalischen ueberreste der Dyas*. Leipzig, Wilhelm Engelmann, pp. i–xvi, 1–130, pls 1–23.

Glushenko, N. V., 1975. Brakhiopody nizhnei Permi i ikh znachenie dlya stratigrafii Vostochno–Ukrainskogo neftegazonosnogo Basseina. In *Stratigrafiya Verkhnego Paleozoya i Nizhnego Mesozoya Dneprovsko–Donetskoi Vpadiny*, I. Yu. Lapkin, ed., Moskva, 'Nedra', pp. 83–118, pls 25–43.

Golovkinskiy, N., 1868. O Permskoi Formatsii v' tsentral'noi chasti Kamsko–Volshskago Basseina. *Materialy dlya Geologii Rossii* 1: 276–415, pls 1–5.

Grigoryeva, A. D., 1962. Produktidy Kazanskogo Yarusa Russkoi Platformy i usloviya ikh Sushchestvovaniya. *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta* 92: 1–92, pls 1–16.

Grigoryeva, A. D., Ganelin, V. G. & Kotlyar, G. V., 1977. Semeistvo Linoproductidae. Akademiya Nauk SSSR, *Trudy Paleontologicheskogo Instituta* 161: 126–165, pls 19–27.

Grunt, T. A. & Dmitriev, V. Yu., 1973. Permskie Brakhiopody Pamira. *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta* 136: 1–212.

Gubareva, V. S., 1998. Brakhiopody. In *Stratotipy i opornye razrezy verkhnei Permi Prikazanskogo Raiona*, B. V. Burov & V. S. Gubareva, eds, Moskva, GEOS, pp. 29–36, 90–91, pls 2–6.

Heywood, P. B., 1978. Stratigraphic Drilling Report—GSQ Eddystone 1. *Queensland Government Mining Journal* 79(922): 407–417.

Hocking, R. M., 1990. Field Guide for the Carnarvon Basin (with notes and additions 1993). *Records of the Geological Survey of Western Australia* 1990/11: 1–74, + 1–6.

Hocking, R. M., Moore, P. S. & Moors, H. T., 1980. Modified stratigraphic nomenclature and concepts in the Palaeozoic sequence of the Carnarvon Basin, W.A. *Reports of the Department of Mines, Western Australia for the year 1979*: 95–99.

Hocking, R. M., Moore, P. S. & Van de Graaff, W. J. E., 1987. Geology of the Carnarvon Basin, Western Australia. *Bulletin of the Geological Survey of Western Australia* 133: i–xiv, 1–289, 3 pls.

Jing, Y.-G. & Sun, D.-L., 1981. Palaeozoic brachiopods from Xizang. *Palaeontology of Xizang*, Book 3: 127–176, pls 1–12.

Kalashnikov, N. V., 1980. *Brakhiopody Verkhnego Paleozoya Evropeiskogo Severa SSSR*. Leningrad, 'Nauka' Leningradskoe Otdelenie, 136 pp., 39 pls.

Kalashnikov, N. V., 1998. *Spiriferidy Permi Evropeiskogo Severa Rossii*. Moskva, GEOS. 139 pp., 32 pls.

Kalashnikov, N. V., Mikhailova, Z. P & Morozova, I. P., 1972. Pervye nakhodki ostatkov morskikh organizmov v otlozheniyakh Tatarskogo Yarusa Yuzhnogo Poberezh'ya Cheshskoi Guby. *Trudy Instituta Geologii, Komi Filiala Akademii Nauk SSSR* 19: 30–59.

Keyserling, A. F. M. L. A. von, 1854. Palaontologische Bermerkungen. In *Reise nach dem Nordosten des Europaischen Russlands, durch die Tundren der Samojeden, zum Arktischen Uralgebirge, fur den Kaiserlichen botanische Garten zu St Petersburg im Jahre 1837 ausgefuhrt*, A. G. Schrenk, ed., Dorpat, Zweiter Theil, pp. 81–114, pls 1–4.

King, W., 1850. A monograph of the Permian fossils of England. *Palaeontographical Society, London*, Monograph 3: i–xxxvii, 1–258, 20 pls.

Klapcinski, J., 1971. Litologia, Fauna, Stratygrafia i Paleogeografia Permu Monokliny Przedsudeckiej. *Geologia Sudetica* 5: 77–135, pls 1–15.

Konecki, M. C., Dickins, J. M. & Quinlan, T., 1958. The geology of the coastal area between the lower Gascoyne and Murchinson Rivers, Western Australia. *Report of the Bureau of Mineral Resources, Geology and Geophysics* 37: 1–144, pls 1–5.

Kutorga, S. S., 1844. Zweiter beitrag zur Palaeontologie Russlands. *Verhandlungen der Russisch–Kaiserlichen Mineralogischen Gesellschaft zu St Petersburg, Jahr 1844*: 62–104, pls 1–10.

Malzahn, E., 1957. Neue fossilfunde und vertikale Verbreitung der niederrheinischen Zechsteinfauna in den Bohrungen Kamp 4 und Friedrich Heinrich 57 bei Kamp-Lintfort. *Geologische Jahrbuch* 73: 91–126.

McClung, G. R., 1978. Permian marine invertebrate macrofossils from GSQ Eddystone 1. *Queensland Government Mining Journal* 79(922): 420–423.

McClung, G. R., 1983. Faunal sequence and palaeoecology of the marine Permian in GSQ Eddystone 1, Denison Trough, Queensland. *Geological Survey of Queensland Publication* 384: 47–80.

Merla, G., 1934. Fossili Antracolitici del Caracorum. *Spedizione Italiana De Filippi, nell'Himalaia, Caracorum e Turchestan Cinese (1913–1914). Serie II Resultati Geologici e geografici*. Vol. 5. I Fossili del Paleozoico, del Paleozoico, pp. 101–319, pls 20–27.

McKellar, J. L., 1978. Palynostratigraphy of samples from GSQ Eddystone 1. *Queensland Government Mining Journal* 79(922): 424–434.

Mory, A. J., 1996. GSWA Ballythanna 1 Well completion report, Byro Sub-basin, Carnarvon Basin, Western Australia. *Record of the Geological Survey of Western Australia* 1996/7: 1–48, 2 pls.

Mory, A. J. & Backhouse, J., 1997. Permian stratigraphy and palynology of the Carnarvon Basin, Western Australia. *Report of the Geological Survey of Western Australia* 51: 1–41, 1 pl.

Muir-Wood, H. M. & Cooper, G. A., 1960. Morphology, classification and life habits of the Productoidea (Brachiopoda). *Geological Society of America Memoir* 81: i–xi, 1–447, pls 1–135.

Nechaev, A. V., 1894. Fauna Permskikh' otlozhenii vostochnoi polosy Evropeiskoi Rossii. *Trudy obshchestva Estestvoispytatelei pri Imperatorskom' Kasanskom' Universitet'* 27(4): 1–503, pls 1–12.

Nechaev, A. V., 1911. Fauna Permskikh' Otlozhenii Vostoka i Krainyago Severa Evropeiskoi Rossii. *Trudy Geologicheskago Komiteto, Novaya Seriyo* 61: 1–165, pls 1–15.

Nie, Z.-T., Song, Z.-M., Jiang, J.-J. & Liang, D.-Y., 1993. Biota features of the Gondwana affinity facies and review of their stratigraphic ages in the Western Yunnan. Geoscience. *Journal of Graduate School, China University of Geosciences* 7(4): 384–393, pl. 1.

Palmieri, V., 1998. Foraminifera zonation in the Permian stratigraphy of the Denison Trough (Bowen Basin), central Queensland. *Proceedings of the Royal Society of Victoria* 110(1/2): 173–195.

Raggatt, H. G., 1936. Geology of North-West Basin, Western Australia, with particular reference to the stratigraphy of the Permo-Carboniferous. *Journal and Proceedings of the Royal Society of New South Wales* 70: 120–174.

Shi, G. R., Fang, Z.-J. & Archbold, N. W., 1996. An Early Permian brachiopod fauna of Gondwanan affinity from the Baoshan block, western Yunnan, China. *Alcheringa* 20: 81–101.

Shi, G. R. & Waterhouse, J. B., 1991. Early Permian brachiopods from Perak, west Malaysia. *Journal of Southeast Asian Earth Sciences* 6(1): 25–39.

Shi, G. R. & Waterhouse, J. B., 1996. Lower Permian brachiopods and molluscs from the Upper Jungle Creek Formation, Northern Yukon Territory, Canada. *Bulletin of the Geological Survey of Canada* 424: 1–241.

Shimizu, D., 1966. Permian brachiopod fossils of Timor (Palaeontological Study of Portuguese Timor, 3). *Memoirs of the College of Science, University of Kyoto, Series B, Geology and Mineralogy* 32(4): 401–427.

Stainbrook, M. A. & Madera, R. F., 1941. A deep subsurface Permian fauna from Hockley Country, Texas. *Journal of Paleontology* 15(4): 376–383.

Stepanov, D. L., 1936. Materialy k poznaniyu brakhiopodovoi fauny verkhnego paleozoya Shpitsbergena. *Uchenye Zapiski Leningradskogo Gosudarstvennogo Universitata, Seriya Geologia I Geografia, Vypusk* 2: 114–128, pls 1–5.

Stepanov, D. L., 1937. Permskie brakhiopody Shpitsbergena. *Trudy Arkticheskogo Instituta* 76: 105–192, pls 1–9.

Stepanov, D. L., 1959. Brakhiopody Litovskogo Tsekhshteina. *Uchenye Zapiski Leningradskogo Gosudarstuennogo Universiteta, 268, Seriya Geologicheskikh Nauk* 10: 190–207, 3 pls.

Stepanov, D. L., ed., 1983. *Opornyi razrez pogranichnykh sloev Karbona i Permi Yuga Vostochno-Evropeiskoi Platform (Gzhel'skii i Assel'skii Yorusy, skvazhina No. 4199 Skosyrskaya).* Leningrad, 'Nauka' Leningradskoe otdelenie, 136 pp., 64 pls.

Stoyanov, A., 1916. O nekotorykh' Permskikh' Brachiopoda Armenii. *Trudy Geologicheskago Komiteta, Novaya Seriya, Vypusk* 111: 1–95, pls 1–6.

Sun, D.-L., 1991. Permian (Sakmarian–Artinskian) brachiopod fauna from Gegyai County, Northwestern Xizang (Tibet) and its biogeographic significance. In *Permian, Jurassic and Cretaceous Stratigraphy and Palaeontology of the Rotog District, Tibet*. D.-L. Sun & J.-T. Yu, eds, Nanjing University Press, Nanjing, pp. 215–275, pls 1–7.

Suveizdis, P. I., ed., 1975. *Permskaya Sistema Pribaltiki (Fauna i stratigrafiya).* Vilnius, Izdvo. MINTIS, 305 pp., 43 pls.

Swarko, S. K., 1993. Palaeontology of the Permian of Western Australia. *Bulletin of the Geological Survey of Western Australia* 136: i–viii, 1–148, 12 microfiche sheets.

Teichert, C., 1952. Carboniferous, Permian and Jurassic in the Northwest Basin, Western Australia. *XIX^e Congres Geologique International, Symposium sur les Series de Gondwana, Alger, 1952*, pp. 115–135.

Termier, H. & Termier, G., 1971. Evolution et Anatomie Fonctionnelle de quelques Productoides. *Bulletin, Societe Geologique et Mineralogique de Bretagne, Serie C*, 3(1): 1–7, 3 figs.

Van de Graaff, W. J. E., Hocking, R. M. & Denman, P. D., 1977. Revised stratigraphic nomenclature and interpretations in the east-central Carnarvon Basin, W.A. *Annual Report of the Geological Survey of Western Australia for the year 1976*: 37–72.

Waterhouse, J. B., 1970. Gondwanan occurrences of the Upper Paleozoic brachiopod *Stepanoviella*. *Journal of Paleontology* 44(1): 37–50, pl. 14.

Zavodovskiy, V. M., 1960. Novye vidy Permskikh produktid i strofalozid Severo-Vostoka SSSR. In *Novye Vidy Drevnikh Rastenii i Bespozvonochnykh SSSR, Chast' Pervaya*, B. P. Markovskii, ed., Gosgeoltekhizdat, Moskva, pp. 332–340, pls 81, 82.

Zavodovskiy, V. M. & Stepanov, D. L., 1970. Tip Brachiopoda–Brakhiopody. In *Polevoi Atlas Permskoi Fauny i Flory Severo-Vostoka SSSR*, M. V. Kulikov, ed., Magadanskoe Knizhnoe Izdatel'stvo, Magadan, pp. 70–182, pls 1–101.